

HETEROMORPH AMMONITES FROM THE ALBIAN OF SOUTH AUSTRALIA

by K. J. McNAMARA*

Summary

McNAMARA, K. J. (1980) Heteromorph ammonites from the Albian of South Australia. *Trans. R. Soc. S. Aust.* **104**(6), 145-159, 28 November, 1980.

The heteromorph ammonite *Protanisoceras* Spath is described from Australia for the first time. Five forms are recognised from the Albian Oodnadatta Formation in South Australia, including *P. auriculum* sp. nov. and *P. gracile* sp. nov. By comparison with species from the Albian of Europe, a Middle Albian age is suggested for part of the Oodnadatta Formation in which they occur. In addition *Appurdiceras cordycepoides* (Etheridge 1905) is redescribed and the relationships of the genus reassessed; a species of *Hamites* is described; and the Late Albian species *Anisoceras sweeti* sp. nov. described.

Introduction

Ammonites form a much less important part of the marine Cretaceous fauna of the Great Artesian Basin in South Australia than in Queensland; hence few species have been described. Albian ammonites were first described from S.A. by Etheridge (1905) who described "*Haploceras* sp., *Anisoceras* (?) sp., *Ancyloceras cordycepoides* and *Crioceras flindersi*" from the area of Dalhousie Springs. The "*Haploceras*" is probably *Falciferella* (see below). Whitehouse (1926) proposed *Appurdiceras* to accommodate *A. cordycepoides*, while "*C.*" *flindersi* belongs in *Myloceras* (Reyment 1964a; McNamara 1978). The only other Albian ammonites to have been described from S.A. are *Falciferella breadeni* and *F. reymonti* Brunnenschweiler (1959) and a Late Albian fauna including species of *Myloceras* and *Labeceras* described by Reyment (1964 a,b). Ludbrook (1966) illustrated specimens which she referred to *Myloceras axonoides* (Etheridge) and *Labeceras papulatum* Whitehouse.

The present study is based primarily on collections from the Albian Oodnadatta Formation housed in the palaeontological collections of the S.A. Department of Mines & Energy (GSSA). The specimens were collected from calcareous nodules, which occur within a soft gypsaceous shale, mainly from Algebuckina 17 (Ludbrook 1966), 32 km SSE of Oodnadatta at lat. 27°49'S, long. 135°34'E. Additional specimens are from Toodla 8, which is 3 km SW of Mt Arthur at lat. 27°31'S and long. 135°41'E (Fig. 1).

Specimens identified from these localities (OODNADATTA 1:250 000 geological map sheet) are:

Protanisoceras auriculum sp. nov., *P. gracile* sp. nov., *P. aff. gracile* sp. nov., *Hamites* cf. *attenuatus* J. Sowerby 1814, *Falciferella* sp. (Ludbrook 1966, p. 44).

The second collection on which this work is based was obtained by G. Sweet from the Maree Subgroup and presented to the National Museum of Victoria (NMV) in 1914. The specimens are recorded as coming from "Primrose Springs, Peake Station". Ludbrook (1966) considered that this locality may be near Primrose Hill at 28°10'S, 136°25'E. From an early description, she now considers that Primrose Hill and Springs is a mound spring with seepage at the base and that the various

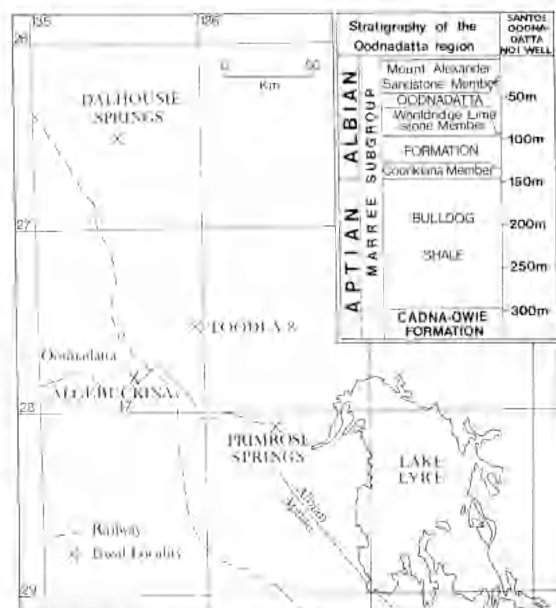


Fig. 1. Map showing fossil localities mentioned in text. Aptian/Albian boundary after Ludbrook (1966, Map 2). Stratigraphic information after Freytag (1966, Fig. 1).

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specimens collected from 'Primrose Springs' are from the general area along The Neales in the NE of the WARRINA 1:250 000 map sheet where both Aptian and Albian strata occur (Ludbrook 1966, Map 6; Thomson 1980). Specimens identified from this locality are:

Anisoceras sweeti sp. nov., *Protanisoceras* sp. A, *P.* sp. B, *Hamites* cf. *attenuatus* J. Sowerby 1814, *Sanmartinoceras* (*Sinzovia*) *fontinale* (Hudleston 1890).

The age of the rocks at this locality is discussed below.

Finally, *Appurdiceras cordycepoides* (Etheridge 1905) is redescribed and reinterpreted on the basis of Etheridge's syntypes from the Oodnadatta Formation at Dalhousie Springs (Fig. 1), one of which is housed in the S.A. Museum (SAM), whilst the other has been located in the NMV. All material was collected from surface outcrop.

Systematic palaeontology

Family ANISOCERATIDAE Hyatt 1900

ANISOCERAS Pictet 1854

Type species: Hamites saussureanus Pictet in Pictet & Roux 1847.

Anisoceras sweeti sp. nov.

FIGS 2, 6D

Etymology: Named after G. Sweet who obtained the specimens.

Holotype: NMV P52328, an incomplete phragmocone from 'Primrose Springs, Peake Station'.

Paratypes: NMV P52325, an incomplete phragmocone, and NMV P52326, an incomplete body chamber; both from same locality as holotype.

Age: Late Albian.

Diagnosis: Species of *Anisoceras* in which lateral and ventro-lateral ribs may cover up to three ribs; ribs broad and strongly prosiradiate on phragmocone. Lateral lobe of suture three times width of umbilical lobe.

Description: Complete shell form unknown; description based on straight fragments. Whorl height slightly greater than whorl width. Phragmocone known from whorl height of 20–24 mm. Ornament consists of coarse, prosiradiate ribs which arise from lateral tubercles in twos or threes, and form loop with circular to elongate ventrolateral tubercles. The looped

ribs form a swollen bundle between which usually lies one relatively depressed intercalated rib between the looped ribs. On dorsum are 12 ribs in a distance equal to the whorl height; ribs well developed on dorsum. Maximum known height of body chamber 27 mm. Ornament similar to that on phragmocone, though tubercles a little more widely spaced. Ventrolateral tubercles more elongate than on the phragmocone. Lateral lobe of suture bifid and large, covering more than half flank of phragmocone; three times width and about twice height of bifid umbilical lobe.

Discussion: *A. sweeti* is similar to *A. armatum* (J. Sowerby 1817) from the Late Albian *Stoliczka dispar* Zone (Cooper & Kennedy 1979; Scholz 1979) in possessing prominent looped ribs with usually one intercalated rib. However, the ribs are only looped in pairs in *A. armatum*. Furthermore the ribs are more strongly prosiradiate in *A. sweeti*. The two species can most easily be distinguished by the relative sizes of the lateral and umbilical lobes of the suture. In *A. armatum* they are of approximately equal size or the lateral is just slightly larger than the umbilical (Scholz 1979, Fig. 8). In *A. sweeti* the lateral lobe is very large, being three times the width of the umbilical lobe.

In *A. haasi* Cooper & Kennedy (1979) three, or four, ribs may be looped between the tubercles. However, the ribs are much finer than in *A. sweeti*.

APPURDICERAS Whitehouse 1926

Type species: Ancyloceras cordycepoides Etheridge 1905 p. 14, Pl. 1, figs 3–5, Pl. 2, fig. 4; by original designation of Whitehouse 1926, p. 229.

Emended diagnosis: Coiling ancyloceratid. Ribs strongly developed, widely spaced; bifurcate laterally and at umbilical tubercles on shaft. Ventrolateral spines regularly developed, bases covering one to three ribs and forming 'loop and button' ornament across venter. Ventrolateral spines on different ribs from umbilical tubercles. Umbilical lobe of suture bifid.

Remarks: Whitehouse (1926) proposed *Appurdiceras* to accommodate *Ancyloceras cordycepoides* Etheridge, distinguishing it from other Australian heteromorphs by its prominent ventrolateral spines. Whitehouse questioningly placed a single labeceratid specimen from Qld in this genus, calling it *A. (?)*

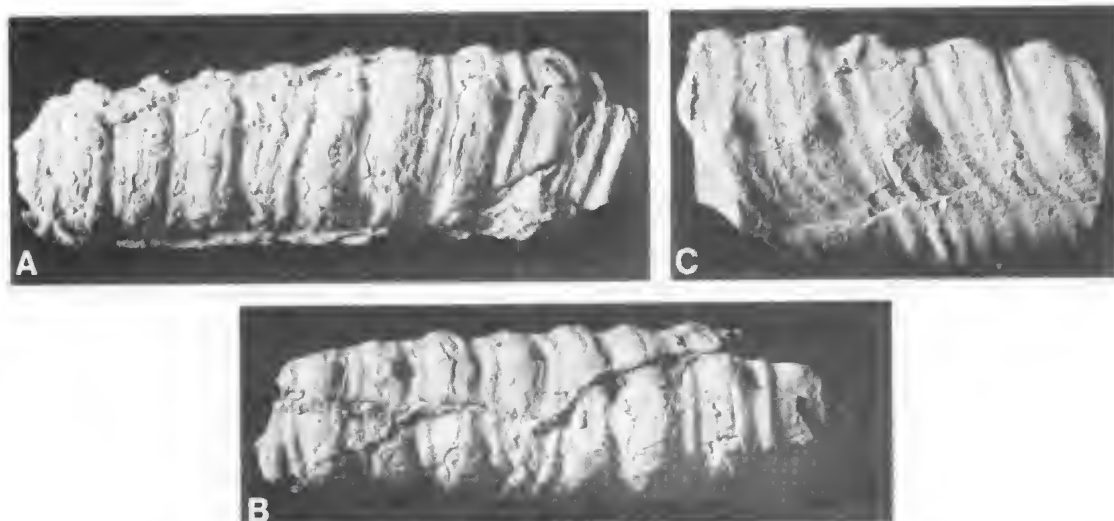


Fig. 2. *Anisoceras sweeti* sp. nov.; NMV P52328, holotype, A, lateral view, B, ventral view; C, NMV P52326, paratype, dorsolateral view; from "Primrose Springs", Peake Station; Oodnadatta Formation, Late Albian; all x 1.

etheridgei, with the result that *Appurdiceras* itself came to be thought of as a subgenus of *Labeceras* (Wright, in Arkell *et al.* 1957; Reyment 1964a; Klinger 1976) which bears ventrolateral tubercles. *A. (?) etheridgei* is quite unlike *A. cordycepoides*, being a true labeceratid which has ribs which do not bifurcate on the flanks of the shaft, as they do in *A. cordycepoides*, and which do not form the characteristic anisoceratid looped ribs across the venter. The umbilical lobe of labeceratids is trifid, whereas in *Appurdiceras* it is bifid.

Consequently, *Appurdiceras* is herein regarded as an anisoceratid and not a subgenus of *Labeceras*. Whitehouse (1926) included *Idiohamites spiniger* (J. Sowerby) from the English Late Albian in *Appurdiceras*. He also noted a similarity with *Hamites nodosus* J. Sowerby. This latter species was made the type of *Heteroclinus* by Casey (1961). However Klinger (1976) places this genus in synonymy with *Protanisoceras* (see below).

Unlike species of *Anisoceras* and *Protanisoceras*, which may bear both ventrolateral and lateral tubercles or spines, *Appurdiceras* possesses ventrolateral and umbilical tubercles. It can also be distinguished from these two genera by the umbilical bifurcation of the ribs on the shaft at tubercles which do not form by the coalescence of the ribs bearing the ventrolateral tubercles or spines, but by the coalescence of an interrelated rib with one which does bear a ventrolateral tubercle. The

ribs may also occasionally bifurcate laterally. Species assigned to *Idiohamites* tend to have numerous, fine ribs between the tuberculate ribs (Spath 1939), though as Klinger (1976) has noted, *Idiohamites* grades into *Anisoceras*. *Anisoceras* and *Protanisoceras* differ from one another in the nature of the suture (see below). Whereas the umbilical lobe is trifid in *Protanisoceras* it is bifid in both *Appurdiceras* and *Anisoceras*.

Appurdiceras cordycepoides (Etheridge 1905) FIG. 3

- 1905 *Ancycloceras cordycepoides* Etheridge, p. 14, Pl. 1, figs 3–5, Pl. 2, fig. 4.
- 1909 *Crioceras cordycepoides* (Etheridge); Etheridge, pp. 142, 156, 159, 160.
- 1926 *Appurdiceras cordycepoides* (Etheridge); Whitehouse, p. 230.
- ?1964 *Labeceras (Appurdiceras) cordycepoides* (Etheridge) Reyment, p. 25, ?Pl. 1, figs 6 & 7.
- 1969 *Appurdiceras cordycepoides* (Etheridge); Day, p. 156.
- non
- 1966 *Labeceras (Appurdiceras) cordycepoides* (Etheridge); Ludbrook, p. 190.

Lectotype: Herein designated: NMV P30032, from Dalhousie Springs (DALHOUSIE 1:250 000 geological map sheet) figured by Etheridge (1905, Pl. 2, fig. 4).

Paralectotype: SAM P2990 from Dalhousie Springs; figured by Etheridge (1905, Pl. 1, figs 3–5).

Age: Late Albian.

Diagnosis: As for genus.

Description: Phragmocone initially ovoid in cross section and forms an open criocone for one whorl, then opens into a shaft. Whorl of lectotype has maximum radius of 22.8 mm. At a quarter whorl, whorl height is 4.5 mm; at commencement of shaft it is 8.5 mm. Early part of whorl damaged, and it is not known whether ribs are tuberculate. Ribs are known, however, to be rectiradiate and not bifurcant. Whorl section of shaft sub-circular. Ornament changes on shaft such that ribs become more widely spaced than on coiled, early part of phragmocone. Early ribs on shaft infrequently bifurcate on flanks. Bifurcations more common along shaft toward crozier. At these bifurcations tubercles are not developed. Bifurcations more commonly occur umbilically between a rib which bears a ventrolateral spine and an intercalated non-spinose rib. Ribs more strongly developed along shaft. Ventrolateral spines appear as rounded tubercles on internal mould. Across venter ribs which connect spines form a raised swollen band. A 'button and loop' ornament is formed across venter by coalescence of three ribs at ventrolateral spines. Initially ribs on shaft rectiradiate, but become increasingly prorsiradiate adaperturally. On dorsum ribs less well-developed, but do not disappear. Shaft almost twice length of maximum diameter of coiled phragmocone. Adaperturally the body chamber recurves to form crozier. Paralectotype reaches a maximum whorl height of 16 mm and a maximum whorl width of 14.5 mm. Suture incompletely known: umbilical lobe bifid and narrow; internal lobe trifid.

Discussion: Since the original description of the two type specimens the only specimens ascribed to this species are two from the Late Albian of Fossil Creek, Wooldridge Limestone Member, Oodnadatta Formation, locality 5/550/1, 42 km NW of Oodnadatta (Reyment 1964a) and specimens from Oodnadatta Formation, Algebuckina 17 (5/571/17), 13 km W of Mt Dutton (Ludbrook 1966). However, it is not possible for me to assign Reyment's fragmentary specimens to *A. cordycepoides* with any certainty as, although seemingly possessing an ovoid to subcircular whorl section and ventrolateral tubercles, there is no indication of bifurcation on the flanks of the shaft. In his description of these specimens Reyment does suggest the presence of occasional bifurcations. If these specimens are true members of *A. cordycepoides* their occurrence with species of *Myloceras* and *Labeceras* indicates that *Appurdiceras* may be a Late Albian form. Specimens referred to *A. cordycepoides* by Ludbrook are species of *Protanisoceras* (see below).

Etheridge's specimens were collected by H. Y. L. Brown from the region of Dalhousie Springs. Ludbrook (1966) has recorded both Albian and Aptian molluscs from this area. In addition to describing *A. cordycepoides* from the Dalhousie area, Etheridge described and illustrated other ammonites which have a Late Albian, rather than Aptian, affinity, including the Late Albian *Myloceras* and *Labeceras*.

The development of ventrolateral spines is seen in other anisoceratids, such as *Anisoceras* (Klinger 1976), *Idiohamites* (Spath 1939)

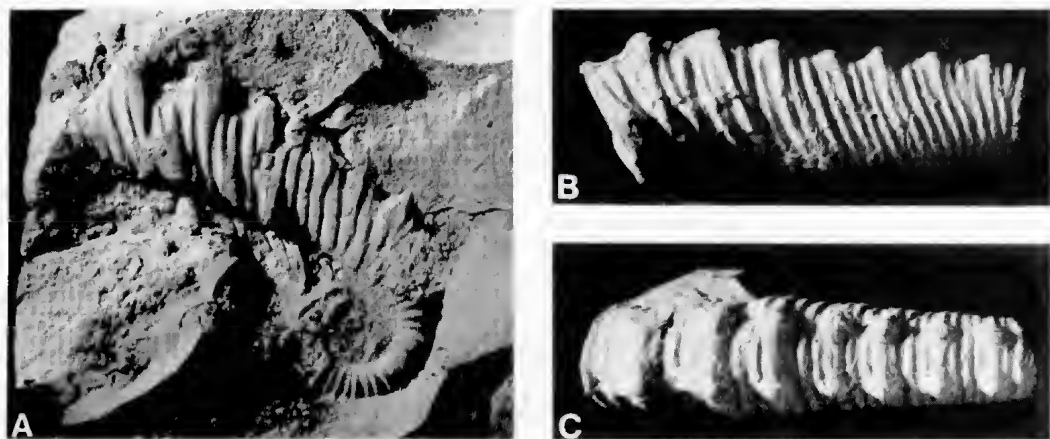


Fig. 3. *Appurdiceras cordycepoides* (Etheridge 1905); A, NMV P30032, lectotype, lateral view; SAM P2990, paralectotype, B, lateral view, C, ventral view; from Dalhousie Springs; Oodnadatta Formation, Late Albian; all x 1.

and *Protanisoceras* (Spath 1939). The two species from the English Late Albian, *Idiohamites spiniger* and *Protanisoceras nodosum*, with which Whitehouse (1926) compared *A.*

cordycepoides, differ in lacking the bifurcation of the ribs on the flank of the shaft and having lateral tubercles developed on the same ribs as the ventrolateral spines.



Fig. 4. *Protanisoceras auriculum* sp. nov.; GSSA M2416, holotype, lateral view; from Algebuckina 17, 32 km SE of Oodnadatta; Oodnadatta Formation, Middle Albian; x 1.

PROTANISOCERAS Spath 1923

Type species: Hamites raulinianus d'Orbigny 1842, p. 546, Pl. 134, figs 5–8; by original designation of Spath 1923, p. 75.

Remarks: Spath (1939) distinguished *Protanisoceras* from the morphologically similar *Anisoceras* by its smaller size, the more regularly planar coiling and simpler suture line which has a trifid umbilical lobe. Klinger (1976) has noted that this lobe is smaller than the lateral lobe in *Protanisoceras*, whereas he believed that it was of similar size to the lateral lobe in *Anisoceras*. The species of *Anisoceras* described here shows that even in some members of this genus the umbilical lobe may be much smaller than the lateral lobe. However, the trifid umbilical lobe of *Protanisoceras* and bifid umbilical lobe of *Anisoceras* are diagnostic.

Klinger (1976) has further noted that the coiling and ornamentation are variable within *Protanisoceras*. Both ventrolateral and lateral, or just ventrolateral tubercles or spines may be present; they may appear on all, or only some, ribs. The tubercles may be connected by one or more ribs. Furthermore, the ornamentation on the recurved crozier may vary considerably from the shaft.

Casey (1961) regarded *P. nodosum* as belonging within a separate genus, which he named *Heteroclinus*, on account of its 'button and loop' ornament. Klinger (1976) has preferred to regard *Heteroclinus* as a synonym of *Protanisoceras* as species such as *P. parce-tuberculatum* Collignon show intermediate characters between *Protanisoceras* and *Heteroclinus* in possessing both single and looped ribs. This situation also occurs in one of the Australian species described below.

***Protanisoceras auriculum* sp. nov.**

FIGS 4, 5, 6B, 9A–C

Etymology: Latin—*auriculum*—ear; pertaining to the shape of the shell.

1966 *Labceras* (*Appurdiceras*) *cordycepoides* (Etheridge) (pars.); Ludbrook, p. 190.

1966 *Myloceras axonoides* (Etheridge); Ludbrook, pp. 44, 190 (pars.), Pl. 28, fig. 1.

Holotype: GSSA M2416, part of the phragmocone and body chamber (Figs 4, 5A); from Oodnadatta Formation, Algebuckina 17 (5/571/17) (Ludbrook 1966), 27°49½'S, 135°34½'E, 32 km SE of Oodnadatta, S.A., on North Creek, near its junction with Neales River (OODNADATTA 1:250 000 geological map sheet).

Paratypes: GSSA M2444, 3546, from the same locality as the holotype and M3547 from Toodla 8 (5/561/8), 3 km SW of Mt Arthur, 27°31'S, 135°41'E.

Other material: In addition to the type specimens, 12 further specimens are known: GSSA M2446, 2454, 3548–3556 from Algebuckina 17 and M3061, 3557 from Toodla 8.

Age: Middle Albian.

Diagnosis: Coiling aspinoceratid. Ventrolateral tubercles occur infrequently on single ribs on early phragmocone and late body chamber; occur more frequently on later phragmocone and early body chamber where they may cover two or three ribs. Ribs broad and widely spaced on early phragmocone; becoming finer and more closely situated adaperturally.

Description: Phragmocone forms open coil throughout. Whorl section ovoid throughout, whorl height slightly greater than whorl width. At earliest known part of phragmocone (Fig. 5E) at whorl height of 4 mm, ornament consists of simple, non-tuberculate, slightly prorsiradiate ribs. At this stage there are four ribs in a distance equal to whorl height. At slightly greater whorl height every fifth or sixth rib is flattened across venter and small tubercles occur ventrolaterally. Up to a whorl height of 9 mm ribs become increasingly prorsiradiate; ribs more strongly inclined toward dorsum. Tubercles at this whorl height occur more frequently and become elongate, spreading across two ribs; up to two intercalated non-tuberculate ribs. Across venter ribs form loop between tubercles and on latter part of phragmocone form swollen band. Tuberculate ribs may also form swollen band on flanks. At whorl height of 10 mm tubercles may cover three ribs and be separated by only one or two intercalated ribs. Ribs on dorsum pass straight across and are weaker than on flanks. Between whorl height 14 mm and 26 mm ribs become more rectiradiate. At whorl height of 30 mm there are 11 ribs in a distance equal to whorl height.

Body chamber commences at whorl height of 32 mm. Tubercles become more widely spaced, covering 2–3 ribs being separated by up to 7 intercalated ribs. Last large tubercles occur at whorl height of 41 mm. Tubercles may become spinose on early body chamber, but progressively decrease in size adaperturally, covering only one rib but occurring on every rib. On body chamber ribs become almost rectiradiate; they become increasingly sinu-

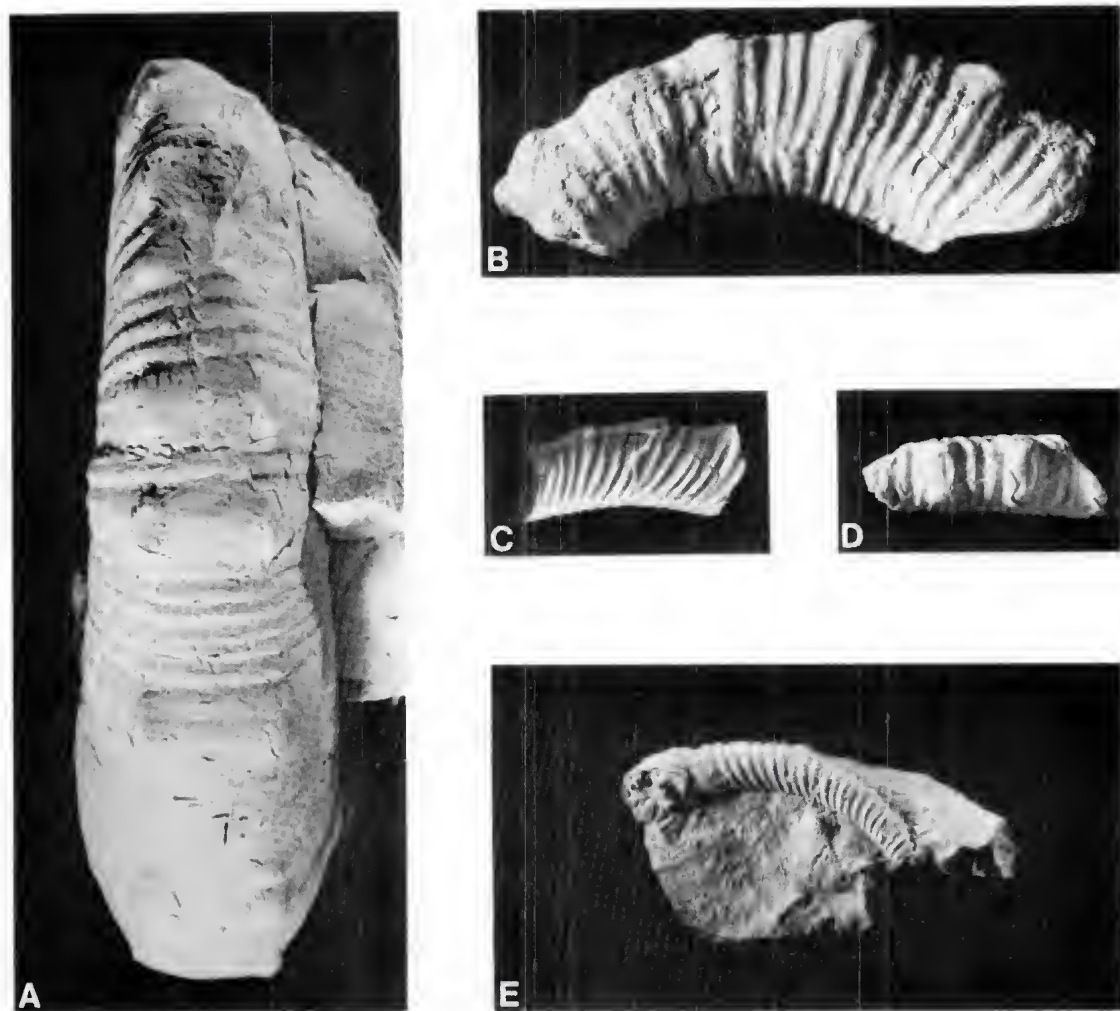


Fig. 5. *Protanisoceras auriculum* sp. nov.; A, GSSA M2416, holotype, ventral view; B, GSSA M2444, paratype, lateral view; GSSA M3547, paratype, C, lateral view, D, ventral view; E, GSSA M3550, lateral view. A, B, E from Algebuckina 17, 32 km SE of Oodnadatta; C, D from Toodla 8, 3 km SW of Mt Arthur; all Oodnadatta Formation, Middle Albian; all x 1.

soidal adaperturally. Body chamber reaches a maximum known whorl height of 50 mm.

Suture line with broad, bifid lateral lobe and small, trifid umbilical lobe, half width of lateral lobe; internal lobe trifid (Fig. 6B).

Discussion: Klinger (1976) has expanded the concept of *Protanisoceras* to include those forms which have tubercles spreading across more than one rib. This looped ornament, so well developed in *P. auriculum*, is seen in the European *loricatus* Zone (mid-Middle Albian) *P. nodosum* and *P. flexuosum* (d'Orbigny). *P. auriculum* can be distinguished from these species by its more elongate tubercles which extend over a greater number of ribs on the

phragmocone, more prorsiradiate ribs and less ornamented body chamber. The Madagascar species *P. paracetuberculatum* Collignon (1962), like *P. auriculum*, possesses both single and looped ribs. It can be distinguished from *P. auriculum* by its narrower ribs and smaller tubercles.

***Protanisoceras gracile* sp. nov.**

FIGS 6A, 7, 9D, E

Etymology: Latin—*gracilis*—slender.

1966 *Labeceras* (*Appurdiceras*) *cordycepoides* (Etheridge) (pars.); Ludbrook, p. 190.

1966 *Myloceras axonoides* (Etheridge) (pars.); Ludbrook, p. 44.

Holotype: GSSA M2455, from Oodnadatta Formation, Algebuckina 17 (5/571/17) (Ludbrook 1966), 27°49'S, 135°34'E, 32 km SE of Oodnadatta, on North Creek, near its junction with Neales River (OODNADATTA 1:250 000 geological map sheet).

Paratypes: GSSA M3558 from same locality as holotype and M3059 from Toodla 8, 3 km SW of Mt Arthur.

Other material: GSSA M2449, 3560–3567 from Algebuckina 17 and M3568–3569 from Toodla 8.

Age: Middle Albian.

Diagnosis: Coiling ancyloceratid; whorl section ovoid, Ventrolateral tubercles infrequent, occurring only on shaft and restricted to single ribs. Ribs prorsiradiate throughout, except on recurved hook where become rectiradiate adaperturally.

Description: Earliest known part of phragmocone with whorl height of 3 mm; moderately strongly coiled; with single, non-tuberculate, gently prorsiradiate ribs. Tubercles first appear at whorl height of 9 mm as small prominences either side of siphonal line. On early part of shaft tubercles occur on about

every sixth rib. At whorl height of 10 mm ribs become sinuously prorsiradiate, more strongly inclined toward dorsum. Ribs thicker and more widely spaced along shaft. At whorl height of 12–14 mm small tubercles present on all ribs in some individuals, but less frequently, or not at all, on others. On recurved body chamber tubercles absent. Adaperturally ribs on body chamber wider and rectiradiate. Whorl section ovoid throughout shell with width 82% whorl height, with maximum whorl height on recurved body chamber of 19 mm. Suture line like that of *P. auriculum*.

Discussion: *P. gracile* can be easily distinguished from *P. auriculum* by its smaller size; possession of a shaft; weaker tuberculation; absence of looped ribs and slightly smaller lateral lobe. *P. gracile* is most similar to *P. nodosum* from the Middle Albian *loricatus* Zone in southern England in lacking lateral tubercles and having ventrolateral tubercles which do not occur on all ribs. *P. gracile* differs in its lack of looped ribs, tubercles which are not spinose, possession of more strongly prorsiradiate ribs and absence of tuberculation on the body chamber. *P. flexuosum*, also from the *loricatus* Zone, simi-

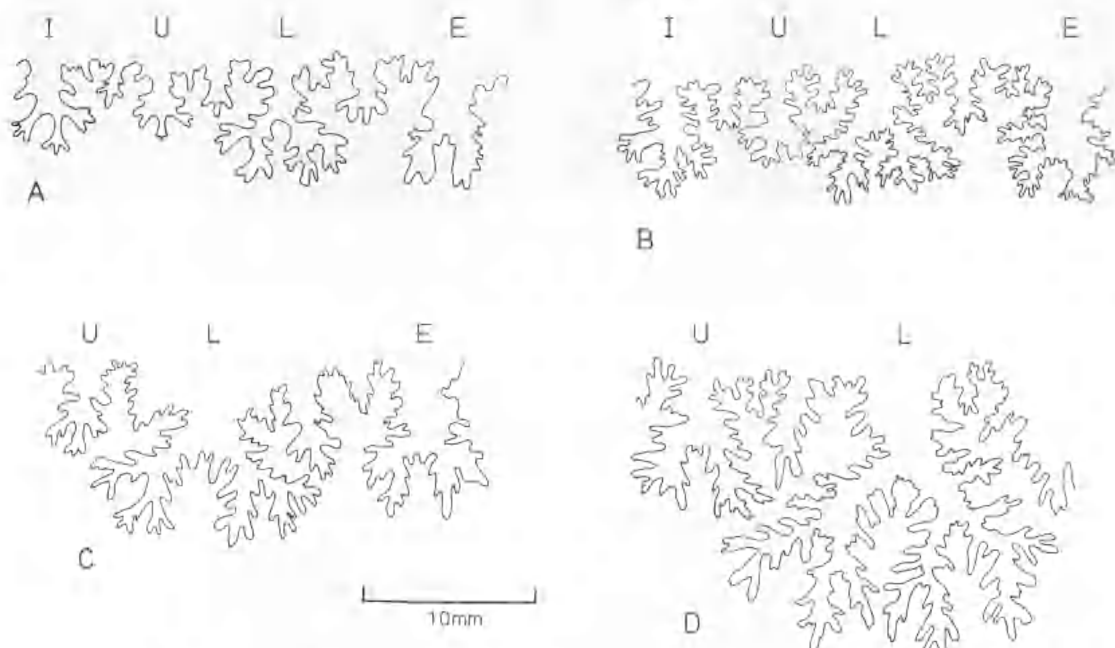


Fig. 6. Suture lines of: A, *Protanisoceras gracile* sp. nov., GSSA M2455, holotype, at whorl height of 12.5 mm; B, *P. auriculum* sp. nov., GSSA M3546, paratype, at whorl height of 16 mm; C, *Protanisoceras* sp. B, NMV P52327, at whorl height of 14 mm; D, *Anisoceras sweeti* sp. nov., NMV P52328, holotype, at whorl height of 23 mm. I = internal lobe; U = umbilical lobe; L = lateral lobe; E = external lobe.

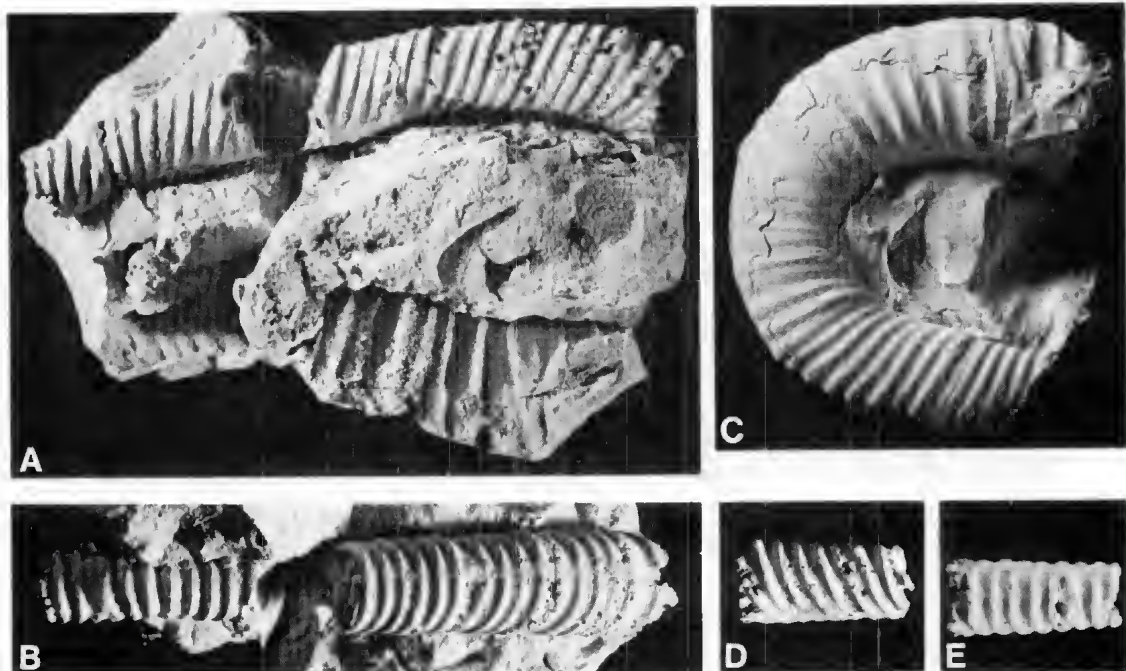


Fig. 7. *Protanisoceras gracile* sp. nov.; GSSA M2455, holotype, A, lateral view, B, ventral view; C, GSSA M3059, paratype, lateral view; GSSA M3558, paratype, D, lateral view, E, ventral view; A,B,D,E, from Algebuckina 17, 32 km SE of Oodnadatta, C from Toodla 8, 3 km SW of Mt Arthur; all from Oodnadatta Formation, Middle Albian; all x 1.

larly lacks lateral tubercles and possesses only small ventrolateral tubereles like *P. gracile*; however in *P. flexuosum* they occur more frequently.

P. gracile is similar to some species from the English Early Albian *mammillatum* Zone, such as *P. raulianum* (d'Orbigny), *P. cantianum* (Spath) and *P. blancheti* (Pietet & Campiche). These species, like *P. gracile*, possess only ventrolateral tubereles and lack looped ribs. However, *P. gracile* can be distinguished from these species by its more strongly prorsiradiate ribs. *P. gracile* resembles *P. gradatum* Collignon (1963, p. 40, Pl. 256, fig. 1101) from the Early Albian of Madagascar, but it is smaller and possesses more inclined ribs.

***Protanisoceras* aff. *gracile* sp. nov.**

FIGS 8, 9F

Material and locality: One specimen, GSSA M2441, from Oodnadatta Formation, Algebuckina 17 (5/571/7), 32 km SE of Oodnadatta (OODNADATTA 1:250 000 geological sheet map).

Age: Middle Albian.

Remarks: This specimen, consisting of the latter part of the shaft and the recurved body

chamber, differs from *P. gracile* in the possession of tubereles which extend across two ribs on the latter part of the phragmocone. Like *P. gracile* the body chamber lacks tubereulation; however, the tighter recurving of the body chamber has resulted in the umbilical bifurcation of some ribs. In terms of whorl section and size this specimen conforms with *P. gracile*, but its more strongly developed tubereulation and tighter recurving are distinctive.

***Protanisoceras* sp. A**

FIGS 9G, 10A, B

Material and locality: An incomplete shaft, NMV P60543, from "Primrose Springs, Peake Station".

Age: Middle Albian.

Description: Whorl section circular with diameter of 16 mm. Ribs slightly prorsiradiate; each rib bears small ventrolateral and lateral tuberele. Tubereles cover only single rib. There are eight ribs in a length equal to whorl diameter.

Discussion: This form can be easily distinguished from *P. sp. B* by the absence of looped ribs with tubereles covering more than one rib.



Fig. 8. *Protanisoceras* aff. *gracile* sp. nov.; GSSA M2441. A, lateral view, B, ventral view; from Algebuckina 17, 32 km SE of Oodnadatta; Oodnadatta Formation, Middle Albian; both x 1.

The absence of suture and the impression of the dorsum of the phragmocone on the matrix attached to the specimen indicate that the specimen is the recurved body chamber. It is a much longer body chamber than possessed by other Australian species of *Protanisoceras* of similar size. The ribbing is finer and more closely spaced than seen in English Early-Middle Albian species. The Middle Albian *P. cantianum* Spath (1939) from southern England has a similar whorl section and tuberculation, but it possesses thicker, more widely spaced ribs.

***Protanisoceras* sp. B**

FIGS 6C, 9H, 10C, D

Material and locality: A single, incomplete phragmocone, NMV P52327, from "Primrose Springs, Peake Station".

Age: Middle Albian.

Description: This specimen, an incomplete, largely internal mould of the latter part of the phragmocone, is characterised by possession of large ventrolateral and lateral tubercles of similar size. Tubercles connected by looped ribs and extend across three ribs; separated by 0–2 intercalated non-tuberculate ribs. Whorl section is semicircular. This form particularly characterised by large, bifid lateral lobe (Fig. 6C) which is almost half as wide again as first saddle; it is four times wider than trifid umbilical lobe.

Discussion: Specimens of *Protanisoceras* described by Klinger (1976) from Zululand

also possess both ventrolateral and lateral tubercles. However, in all the forms Klinger described the tuberculate ribs are much more widely separated by non-tuberculate ribs than in the S.A. forms. *P. sp. B* compares with some English Late Albian species of *Anisoceras*, such as *A. armatum*, in the nature of the tuberculation; however, whereas species of *Anisoceras* possess a bifid umbilical lobe it is trifid in *P. sp. B*. The ornamentation is like that of *A. sweeti*. The two species can be distinguished by the nature of the umbilical lobe and the smaller size of *P. sp. B*. This species differs from *P. auriculum* and *P. gracile* in its possession of lateral tubercles.

Family HAMITIDAE Hyatt 1900

HAMITES Parkinson 1811

Type species: *Hamites attenuatus* J. Sowerby 1814, by subsequent designation of Diener 1925, p. 65.

***Hamites* cf. *attenuatus* J. Sowerby 1814**

FIG. 11

Material and localities: A complete body chamber, NMV P52336 from "Primrose Springs, Peake Station", and an incomplete body chamber, GSSA M2447, Oodnadatta Formation, Algebuckina 17 (5/571/17).

Age: Middle Albian.

Remarks: The well preserved body chamber has an almost circular whorl section. Like *H. attenuatus* from the Middle Albian *dentatus-*

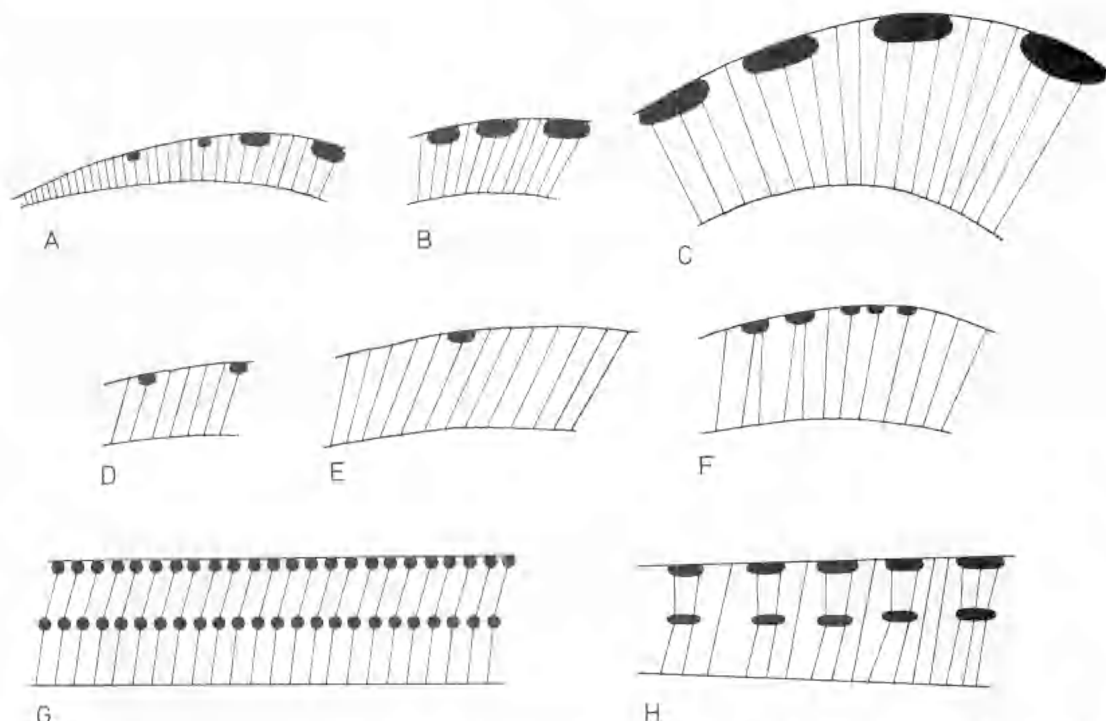


Fig. 9. Diagrammatic representation of variation in distribution of ribs and tubercles in species of *Protaniloceras*. A–C, *P. auriculum* sp. nov., A, GSSA M3550, B, GSSA M3547, paratype, C, GSSA M2444, paratype; D–E, *P. gracile* sp. nov., D, GSSA M3558, paratype, E, SADM M2455, holotype, F, *P. aff. gracile* sp. nov., GSSA W2441; G, *P. sp. A*, NMV P60543; H, *P. sp. B*, NMV P52327. All natural size.

loricatus Zones of southern England, the S.A. form possesses ribs which are slightly prorsiridiate prior to the hook; rectiradial on the hook, becoming initially rursiradial on the recurved shaft, then finally rectiradial. Similarly it has 7–8 ribs in a length equal to the whorl diameter. The whorl section of the English form is said to be slightly laterally compressed (Spath 1939) whereas it is slightly dorsoventrally compressed in the S.A. form.

In both forms the adapertural part of the body chamber curves away from the phragmocone. The impression of the dorsum of the phragmocone against the body chamber (Fig. 11A) shows that the body chamber was deflected away from the phragmocone during growth as the two shafts came into contact.

The suture line of the S.A. form is of similar proportions to the English form, with a bifid lateral lobe and small trifid umbilical lobe. Whitehouse (1926) described a form from the Albian of Qld which he called *H. aff. maximus* J. Sowerby. This specimen, as can be seen in Whitehouse's figure, possesses a trifid

lateral lobe, whereas in *Hamites* it is bifid; it is thus not a species of *Hamites*.

Age of the ammonites

The Marree Subgroup comprises the Aptian Bulldog Shale and the Albian Oodnadatta Formation (Freitag 1966, Ludbrook 1966, 1978, 1980). Since Ludbrook's (1966) biostratigraphical study was submitted for publication, the OODNADATTA 1:250 000 geological map sheet has been published (Freitag *et al.* 1967) and the rock units comprising the Aptian-Albian sequence named in some detail (Freitag 1966). It is now possible to relate the ammonites to the rock units, as mapped on the OODNADATTA and adjoining sheets, from which most of them were collected.

The ammonite *Sanmartinoceras* (*Sinzovia*) *fontinale* from the Marree Subgroup at 'Primrose Springs, Peake Station' was described by Hudleston (1890). Thomson (1974) discussed the range of *Sanmartinoceras* and believed that it is, by and large, an Aptian form. The occurrence of *S. (Sinzovia)* in association with *Tropaeum* in Qld led Day (1969) to conclude

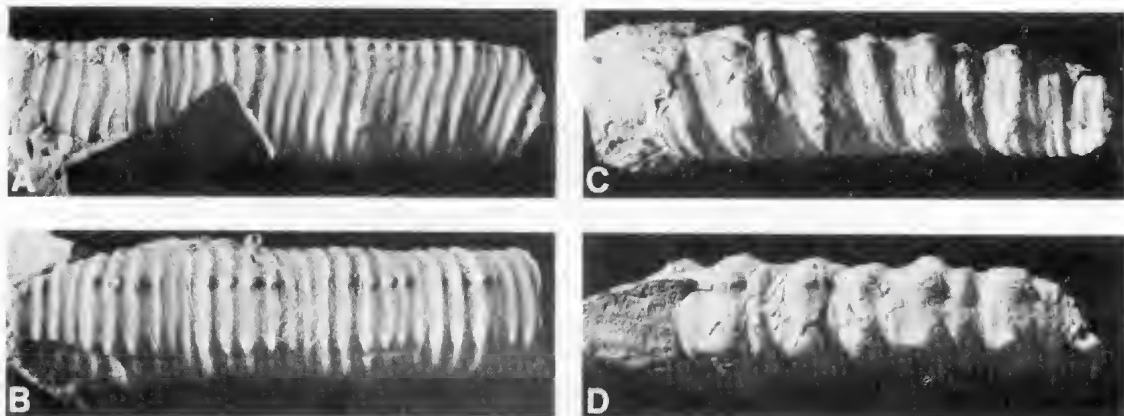


Fig. 10. *Protanisoceras* sp. A; NMV P60543, A, lateral view, B, ventral view. *Protanisoceras* sp. B, NMV P52327, C, lateral view, D, ventral view. Both from "Primrose Springs, Peake Station"; Oodnadatta Formation, Middle Albian, both x 1.

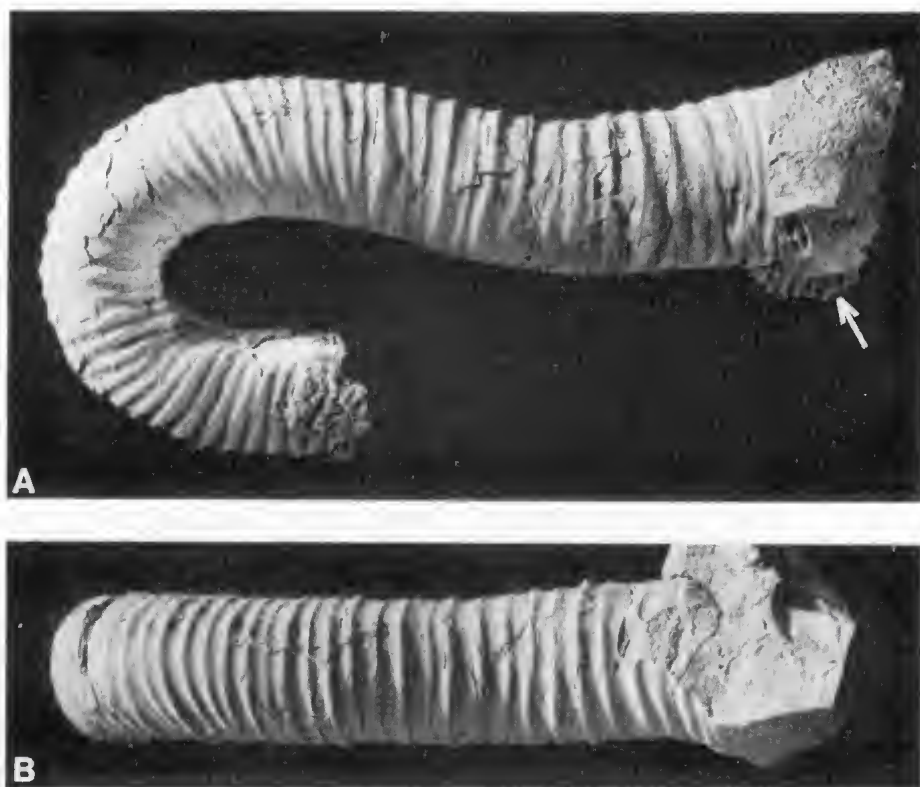


Fig. 11. *Hamites* cf. *attenuatus* J. Sowerby 1814; A, lateral view, B, ventral view; from "Primrose Springs, Peake Station"; Oodnadatta Formation, Middle Albian; x 1. Arrow indicates impression of dorsum of part of phragmocone.

a Late Aptian age for the genus in Australia. A Late Aptian age for part, at least, of the Bulldog Shale is further indicated by the presence of *Tropaeum* in S.A. (Howehin & Whitehouse 1928).

In her biostratigraphical study of the Cretaceous rocks of the Great Artesian Basin in S.A. Ludbrook (1966) concluded that there was no reliable means of establishing a detailed biostratigraphic zonation of the

Marree Subgroup between the Late Aptian and Late Albian on the evidence of ammonites. Part of the reason for this has been the attribution of any small heteromorph ammonite found in the formation to the Late Albian genera *Myloceras* or *Labeceras* (e.g. Ludbrook 1966), although it has now been shown that a number of other genera are present. It also stems from the inaccurate statement of Brunnenschweiler (1959) who, in describing species of *Falciferella* from the Santos Oodnadatta No. 1 Well, stated, "The beds from the surface down to about 375 feet contain also *Myloceras*, *Labeceras*, *Appurdiceras*, *Boliteceras* etc., and are to be regarded as early Upper Albian . . ."; *Falciferella* he recorded between 71.5 m (235 ft) and 113.3 m (372 ft). This led Brunnenschweiler to conclude that *Falciferella* was of Late Albian age in Australia (even though it is restricted to the Middle Albian *intermedius* and *niobe* Subzones of the *loricatus* Zone in England (Owen 1971)) as the *Labeceras*-*Myloceras* fauna in Qld, Madagascar and Zululand has been established as Late Albian (Whitehouse 1926, Klinger 1976, McNamara 1978). However, as Ludbrook (1966) has noted, this Late Albian fauna does not occur with *Falciferella* in the Oodnadatta No. 1 Well. Brunnenschweiler was probably referring to the Late Albian ammonite fauna at Fossil Creek (Reyment 1964 a,b).

Ludbrook (1966) placed the "unnamed green-sand member" (now the Coorikiana Member of the Oodnadatta Formation), which occurs in Santos Oodnadatta No. 1 Well between 131 and 137 m, at the base of the Albian. She records *Falciferella* in the well between this member and the top of the Oodnadatta Formation, which is thought to be of Late Albian age (Ludbrook 1978), at about 91 m. This is suggestive of a Middle Albian age for *Falciferella* in Australia as in England.

Cooper & Kennedy (1979) have recently placed the two described Australian species *F. breadeni* and *F. reymonti*, in the binneyitid *Borissiakoceras*, which, apart from an incomplete specimen from the uppermost Albian of Angola, is restricted to the Late Cenomanian to Early Turonian (Wright in Arkell *et al.* 1957). Cooper & Kennedy consider that there is a direct phylogenetic relationship between the Middle Albian *Falciferella*, with its falcoid growth lines and ribs, and the almost smooth *Borissiakoceras*. Following Brunnenschweiler's assignment of a Late Albian age to

F. breadeni and *F. reymonti*, Cooper & Kennedy suggested that these species may belong in *Borissiakoceras*. However, these species, like the type species of *Falciferella*, *F. millbourni* Casey (1954), have fine ribs on the body chamber, and a trifid lateral lobe, which in *Borissiakoceras* is bifid (Cobban 1961). Examination of the type and topotype material of *F. breadeni* from the Oodnadatta Formation, revealed the suture line to be more crenulate than shown by Brunnenschweiler (1959), being very close to that of *F. millbourni*. Furthermore the occurrence of *F. breadeni* and *F. reymonti* with the Middle Albian species of *Protanisoceras* (see below) and a Middle Albian species of *Hamites*, and possessing ribbing which is more akin to *Falciferella* than to *Borissiakoceras*, suggest that Brunnenschweiler's original emplacement in *Falciferella* is more appropriate. Obviously there is a close relationship between these two genera, sufficient for Kennedy & Juignet (1973) to have placed *Falciferella* in the Binneyitidae and not the Oppeliidae as did Wright (in Arkell *et al.* 1957).

At Algebuckina 17 *Falciferella* occurs (Ludbrook 1966) with *Protanisoceras auriculum* and *P. gracile*. Species of *Protanisoceras* also occur at "Primrose Springs, Peake Station". *Protanisoceras* was considered by Wright (in Arkell *et al.* 1957) to range from the Early-Middle Albian. The youngest species in the English Middle Albian occurs in the *intermedius* Subzone of the *loricatus* Zone (Owen 1971). Klinger (1976) extended its lower range into the Late Aptian. Casey (1961) has shown that the earliest English Albian species of *Protanisoceras*, which appear in the *floridum* Subzone of the *mammillatum* Zone, compare closely with contemporaneous species of *Hamites*, differing only in the development of small ventrolateral tubercles which cover single ribs. In the succeeding *raulianum* and *puzianus* Subzones there is a general trend toward increasing tuberculation, the species possessing more frequent and prominent ventrolateral tubercles and the development of lateral tubercles; these species coexist with poorly tuberculate species. In the early Middle Albian *dentatus* and early *loricatus* Zones (Spath 1939) species with lateral tubercles predominate, and an increasing number of species, such as *P. nodosum* and *P. flexuosum* of the *loricatus* Zone (Owen 1971), have looped ribs. In these later species there is a loss of lateral tubercles, as occurs in *P. auriculum* and *P. gracile*.

The occurrence at Algebuckina 17 of species of *Protanisoceras* morphologically closest to the *loricatus* Zone species, coexisting with species of *Falciferella*, which occurs only in the first two subzones of the *loricatus* Zone (Owen 1971), and with *Hamites* cf. *attenuatus*, which ranges from the late *dentatus* Zone through the *loricatus* Zone, suggests that this part of the Oodnadatta Formation may correlate with the mid-Middle Albian *loricatus* Zone of the Anglo-Paris Basin.

The locality cited as "Primrose Springs, Peake Station" in the old literature probably includes more than one locality, as stated above. Until the WARRINA 1:250 000 geological map sheet is mapped in detail, it will not be possible to identify the precise localities from which the Late Aptian *Sanmartinoceras* (*Sinzovia*) *fontinale*, and the Middle Albian species of *Protanisoceras* with looped ribs and *Hamites* cf. *attenuatus*, were collected. In addition, the occurrence of *Anisoceras* *sweeti*

indicates that younger strata also outcrop in this region, as the genus ranges from the Late Albian to the Late Turonian (Wright in Arkell *et al.* 1957). As the Blanchewater Formation which overlies the Marree Subgroup in the Marree area is thought to be latest Albian in age, possibly extending into the Cenomanian (Ludbrook 1966, 1978), the upper part of the Oodnadatta Formation is early Late Albian in age. This has been established at Fossil Creek by the presence of *Myloceras* and *Labeceras*.

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AGES AND ASHES IN LAKE FLOOR SEDIMENT CORES FROM VALLEY LAKE, MT GAMBIER, SOUTH AUSTRALIA

BY C. E. BARTON & M. W. McELHINNY

Summary

A set of our cores from Valley Lake shows a sequence of fresh water organic muds above a band of aragonite 8-10 cm thick, overlying a graded calcareous tuff. Magnetic remanence and susceptibility measurements indicate the absence of volcanic episodes since the onset of deposition of the organic muds 5000 to 6000 years ago. Radiocarbon ages of ~14 000 years and ~38 000 years for the aragonite band and the tuff respectively are not considered to reflect their ages of formation.